THE ZERO DEFECT COMPANY

XEBEC S1420 GENERAL PURPOSE DISK CONTROLLER FOR 5.25" HARD DISK DRIVES AND 5.25" FLOPPY DISK DRIVES

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CHAPTER 1
INTRODUCTION

GENERAL

The Xebec S-1420 Disk Controller can control the operation of one or two 5¼-inch Winchester hard disk drives and one or two 5¼-inch floppy disk drives that have the industry standard interface.

DESCRIPTION

The S1420 Controller, shown in Figure 1-1, is packaged on a compact printed circuit board whose dimensions are 5-3/4 by 8 inches. The board with this popular form factor mounts easily on many 5¼-inch drives. If not mounted directly on the drive, the Controller takes up very little space in a typical drive enclosure. And because the Controller uses the Shugart Associates System Interface (SASI), it does not require special or complex design considerations in order to communicate with popular host buses. The following list highlights the operating and design features of the Controller.

- Interlocked data transfer through the Shugart Associates System Interface (SASI).
- Microprocessor-based architecture (patent pending).
- Full-sector buffer.
- Hardware 32-bit ECC polynomial with 11-bit burst correction for hard disk.
- Field-proven data separator.
- Hardware 16 bit CRC polynomial for floppy disk.
- Automatic retries during disk access.
- Internal Diagnostics.
- Automatic burst error detection and correction.
- Separate sector format for ID and data fields with individual check fields for both the ID and data fields.
- High level command set.

FUNCTIONAL ORGANIZATION

The simplified block diagram in Figure 1-2 shows the functional organization of the Controller. Only the major areas are shown.

1.3.1 Host Interface

The host interface connects the internal data bus to the host adapter; the state machine controls the movement of data and commands through the host interface.

1.3.2 Processor

The eight-bit processor is the intelligence of the Controller; it monitors and controls the operation of the Controller.

1.3.3 State Machine

The state machine controls and synchronizes the operation of the host adapter, SERDES, and sector buffer for the hard disk.

1.3.4 SERDES

The serializer/deserializer (SERDES) converts parallel data from the internal data bus to serial data for transfer to a selected hard disk drive. It converts serial data from the selected disk drive to parallel data which it places on the internal data bus.

1.3.5 Data Separator

The data separator converts serial NRZ data to MFM for transfer to the selected hard disk drive. It converts MFM data coming from the selected drive to parallel data which it places on the internal data bus.

1.3.6 Sector Buffer

The sector buffer stages data transfers between the disk and the host to prevent data overruns.

1.3.7 Floppy Disk Controller

The Floppy Disk Controller (FDC) is an intelligent LSI device capable of executing the lowest level tasks necessary to control a floppy disk drive.

FIGURE 1-1 S1420 DISK CONTROLLER

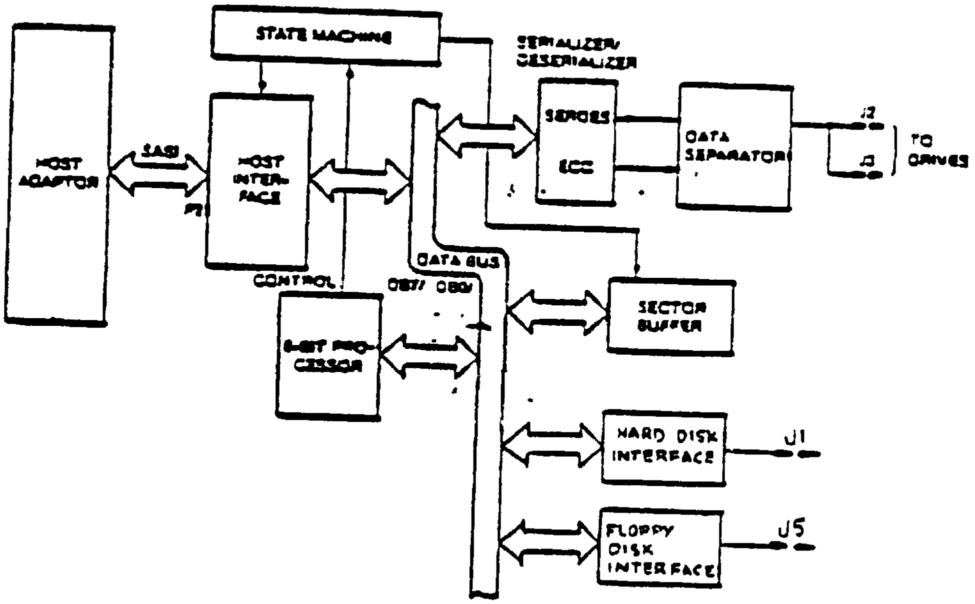

FIGURE 1-2 S1420 CONTROLLER, FUNCTIONAL ORGANIZATION

CHAPTER 2
SPECIFICATIONS

2.1 GENERAL

This chapter contains the overall specifications for the Controller. These specifications are meant to guide the user in placing the Controller into operation. Some of the specifications indicate limits; the user must adhere to these in order to operate the Controller successfully.

2.2 ELECTRICAL

Table 2-1 lists the electrical requirements of the Controller.

TABLE 2-1 CONTROLLER ELECTRICAL REQUIREMENTS

NOTE: All measurements are made on the Controller printed circuit board at the power connector P1.

Voltage	Range	Current	
+5.0 Vdc	4.75 to 5.25 Vdc	2.5	Amp. Max.
		2.0	Amp. Typ.
+12.0 Vdc	10.8 to 13.2 Vdc	3.0	ma. Max.
		1.0	ma. Typ.

Note: The maximum conducted power supply ripple must not exceed 0.10 volts rms, from 0.1 to 25 mHz.

2.3 PHYSICAL SPECIFICATIONS

Table 2-2 lists the specifications of the Controller board and Figure 2-1 illustrates the dimensions of the board.

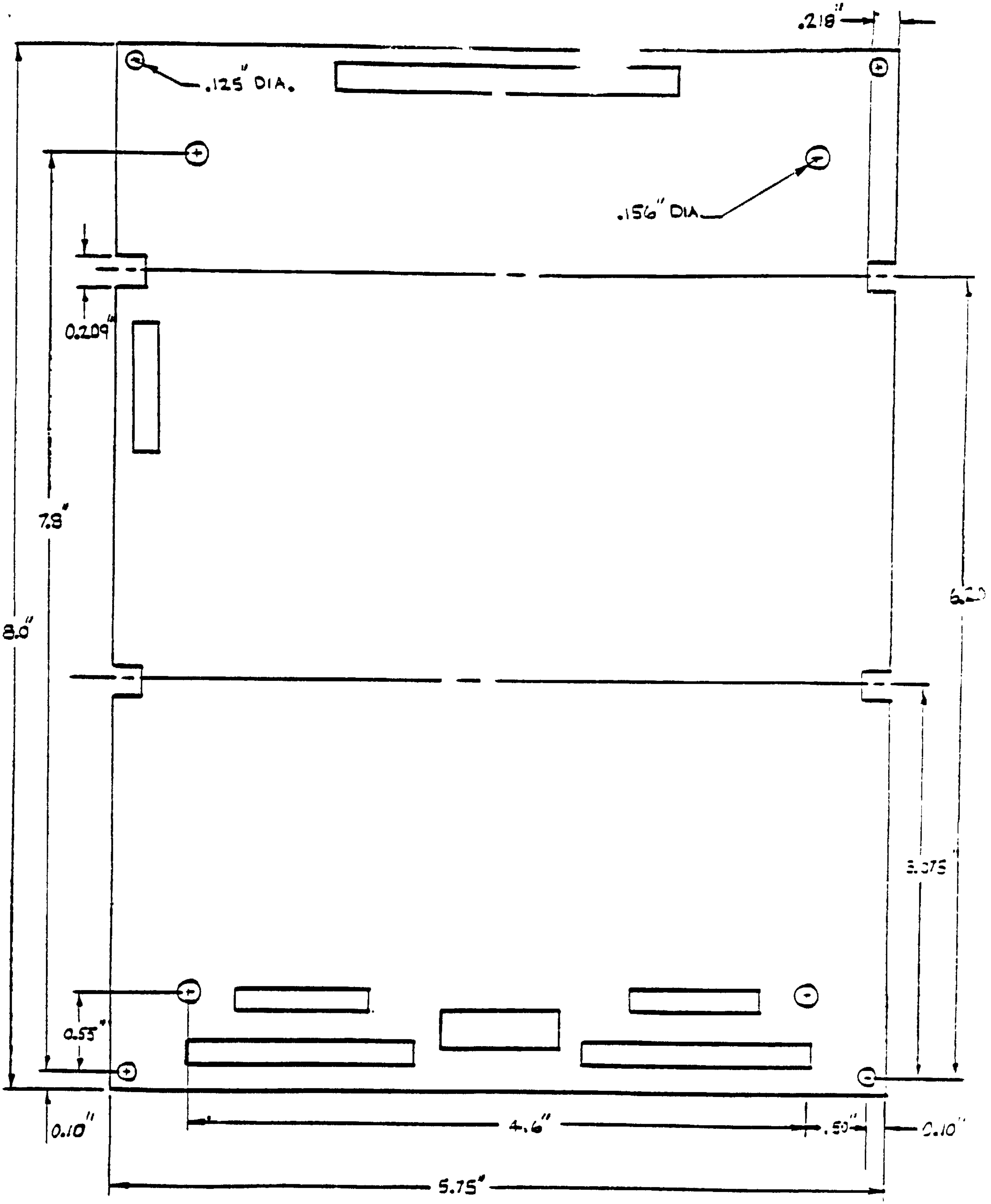

FIGURE 2-1 CONTROLLER BOARD DIMENSIONS

TABLE 2-2 CONTROLLER BOARD SPECIFICATIONS

ITEM	MEASUREMENT
Width (W)	5.75 inches
Length (L)	8.00 inches
Height (H) (Board thickness, components and lead protrusion)	.69 inches
Weight	9.0 ounces

2.4 ENVIRONMENTAL REQUIREMENTS

The Controller will operate under the environmental conditions listed in Table 2-3. The Controller does not normally require fans in standard operating environments where airflow is not restricted.

TABLE 2-3 ENVIRONMENTAL LIMITS

ITEM	MEASUREMENT
Temperature	0 to 50 degrees Celsius
Relative Humidity	10 to 95 percent
Altitude	Sea level to 10,000 feet

2.5 CONNECTORS

Table 2-4 lists the Controller mating connectors.

TABLE 2-4 CONTROLLER MATING CONNECTORS

DESIG-		TYPE/SOURCE
NATION	FUNCTION	(OR EQUIVALENT)
J1, J5	Drive control signals	AMP 88376-6
J2, J3	Drive data signals	AMP 86904-1
J4	Test connector	Not applicable

NOTE: The user **must not** connect a cable to connector J4.

P1	Power Supply	AMP 1-480424-0 (housing)
		AMP 350078-4 (pins)
P2	Host interface signals	AMP 86916-1

2.6 CONNECTOR PIN ASSIGNMENTS

Tables 2-5 through 2-9 list the pin assignments of the connectors on the Controller board. The tables identify the signals on the pins. The signals in Table 2.6 are defined in Chapter 4, Theory of Operation.

TABLE 2-5 CONNECTOR J1
HARD DISK CONTROL SIGNALS, PIN ASSIGNMENTS

SIGNAL PIN	GROUND RETURN	SIGNAL NAME
2	1	Reduced Write Current-
4	3	Head 2^2-
6	5	Write Gate-
8	7	Seek Complete-
10	9	Track 000-
12	11	Write Fault-
14	13	Head Select 2^0-
16	15	Reserved
18	17	Head Select 2^1-
20	19	Index-
22	21	Ready-
24	23	Step-
26	25	Drive Select 1-
28	27	Drive Select 2-
30	29	Reserved
32	31	Reserved
34	33	Direction In-

TABLE 2-6 CONNECTORS J2 AND J3, HARD DISK DATA SIGNALS, PIN ASSIGNMENTS

SIGNAL PIN	GROUND RETURN	SIGNAL NAME
1	2	Drive Selected-
3	4	Reserved
5	6	Spare
7	8	Reserved
-	-	Spares, pins 9 and 10
11	12	Ground (GND)
13		MFM Write Data
14		MFM Write Data-
15	16	Ground (GND)
17		MFM Read Data
18		MFM Read Data-
19	20	Ground (GND)

TABLE 2-7 CONNECTOR J5
FLOPPY DISK SIGNALS, PIN ASSIGNMENTS

PIN NUMBER	SIGNAL NAME
2	-
4	-
6	-
8	Index
10	Drive Select 0-
12	Drive Select 1-
14	-
16	Motor On-
18	Direction
20	Step-
22	Write Data-
24	Write Enable-
26	Track 00-
28	Write Protect-
30	Read Data-
32	Side Select-
34	-

TABLE 2-8 CONNECTOR P2, HOST INTERFACE PIN ASSIGNMENTS

[illegible]

PIN NUMBER	[illegible]	SIGNAL NAME	
✓ 2	8	DATA0-	[illegible]
✓ 4	21	DATA1-	[illegible]
✓ 6	22	DATA2-	14
✓ 8	10	DATA3-	16
✓ 10	23	DATA4-	18
✓ 12	11	DATA5-	24
✓ 14	12	DATA6-	
✓ 16	13	DATA7-	
✓ 18	20	Spare [illegible]	
20	—	Spare	
22	—	Spare	
24	—	Spare	
26	25	Spare Term Power	
28	—	Spare	
30	—	Spare	
✓ 32	17	Spare [illegible]	
34	—	Spare	
✓ 36	6	BUSY-	
✓ 38	5	ACK-	
✓ 40	4	RST-	
✓ 42	2	MSG-	
✓ 44	19	SEL-	
✓ 46	15	C/D	
✓ 48	1	REQ-	
✓ 50	3	I/0	

TABLE 2-9 CONNECTOR P1, POWER SUPPLY, PIN ASSIGNMENTS

PIN NUMBER	VOLTAGE
1	+12 Vdc
2	Ground return
3	Ground return
4	+5 Vdc

CHAPTER 3
BOARD SETUP

GENERAL

This chapter contains the information for setting up and installing the Controller before placing it in operation. These preparatory steps require mounting the Controller in its operating environment, and properly connecting the cables. In addition, the user has the option of using more than one controller with the host adapter in his system. Instructions for connecting multiple controllers appear later in the chapter.

BOARD SETUP

There are no user configurable hardware options on the S1420 Controller except board address selection. Address selection is discussed in Section 3.6.

MOUNTING CONTROLLER

The Controller board has four mounting holes. It can be mounted anywhere within the drive enclosure so long as it receives airflow.

CONNECTING CABLES

Before the Controller can be placed in operation, the cables to the drive and host must be connected. These cables are listed below:

J1	Control Cable (controller to last drive): maximum 20 feet
J2	Data Cable: maximum 20 feet
J3	Data Cable: maximum 20 feet (optional second drive)
J5	Floppy Disk Control Cable: maximum 20 feet
P1	Power Cable
P2	Host Interface Cable: maximum 15 feet

If using only one drive, Data Cable connector J2 or J3 may be used (i.e., single drive does not have to be connected to J2 only).

Note: Do not attempt to connect a cable to connector J4. Connector J4 is for factory test only.

Figure 3-1 shows the connector locations.

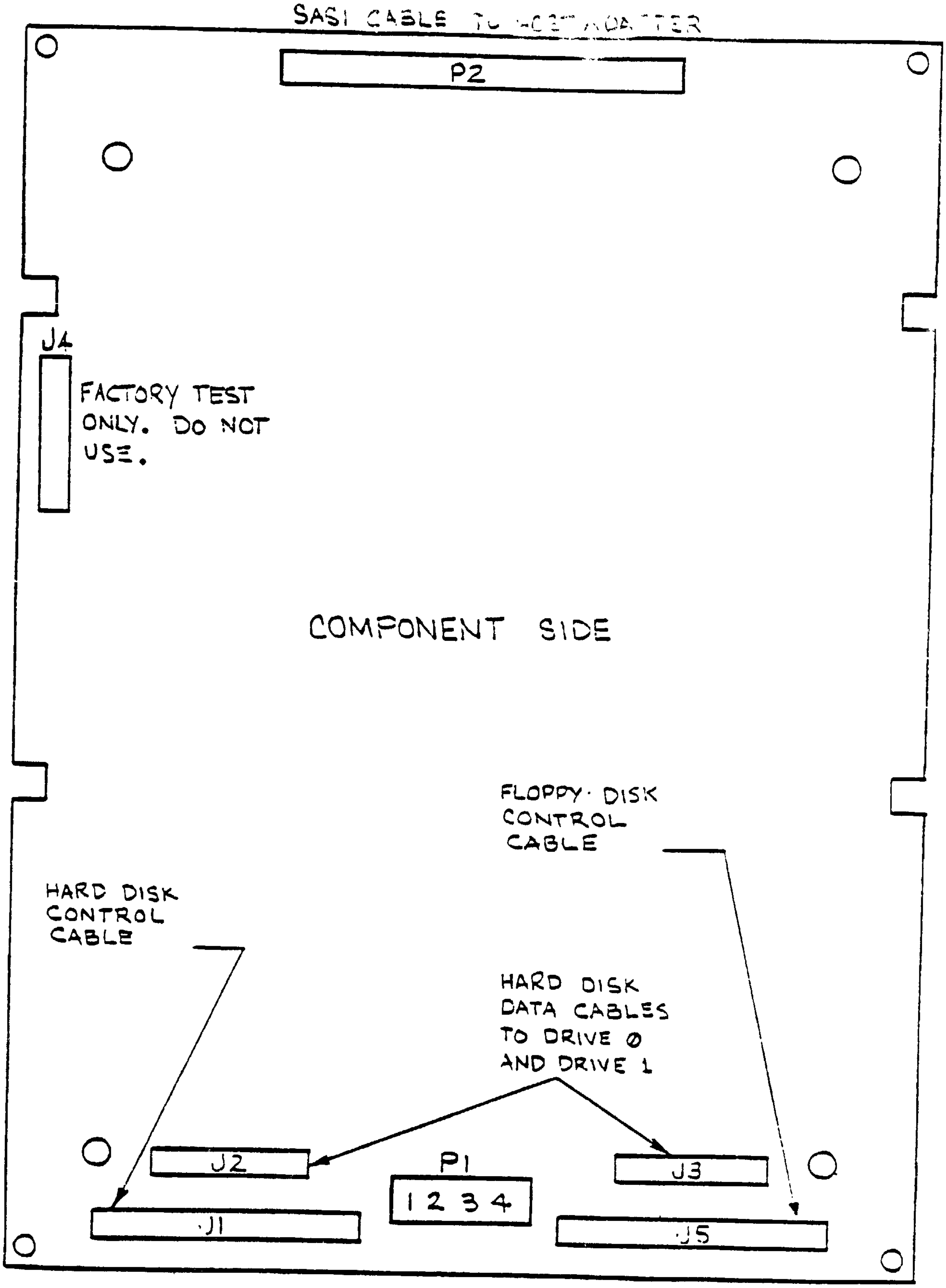
SASI CABLE TO HOST ADAPTER
P2
J4
FACTORY TEST ONLY. DO NOT USE.
COMPONENT SIDE
FLOPPY DISK CONTROL CABLE
HARD DISK CONTROL CABLE
HARD DISK DATA CABLES TO DRIVE Ø AND DRIVE 1
J2
P1
1 2 3 4
J3
J1
J5

FIGURE 3-1 CABLE, CONNECTOR, AND JUMPER LOCATIONS

MULTIPLE CONTROLLERS

A separate Controller is required for each additional pair of drives. Figure 3-2 shows two operating setups: (A) using one controller and (B) using two controllers. Notice the terminator (resistor pack) in both drawings. The terminator is at position 7D on the board in a socket near Pin 1 on connector P2; when multiple controllers are used, the terminator must be installed only in the last board in the daisy chain.

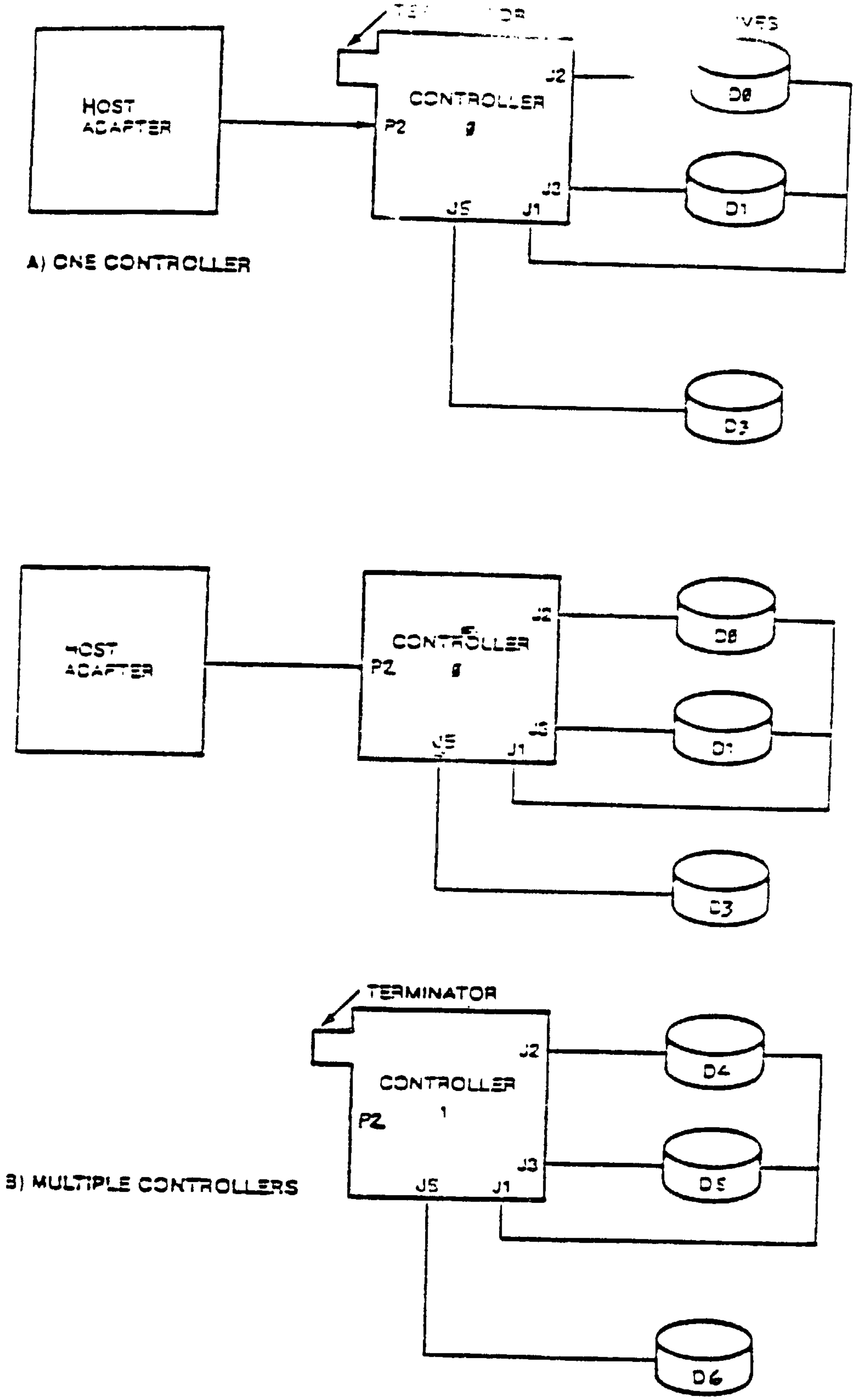

FIGURE 3-2 OPERATING SETUPS

3.6 ADDRESS JUMPER GROUP

The Controller supports one of eight unique device addresses. When more than one controller is used in a system, the address jumper on the Controller must be changed. Figure 3-3 shows the address jumper group located next to position 7B; it also shows that terminal (pad) 0 is connected to terminal S. This is the factory-installed jumper, and it sets the Controller's address to 0.

In order to change this address, the factory-installed jumper must be cut. Then, a new jumper must be connected between terminal S and the selected address terminal. Figure 3-4 shows that the factory-installed jumper has been cut, and a new jumper has been installed between terminal S and address terminal 1. The address of the Controller is now 1.

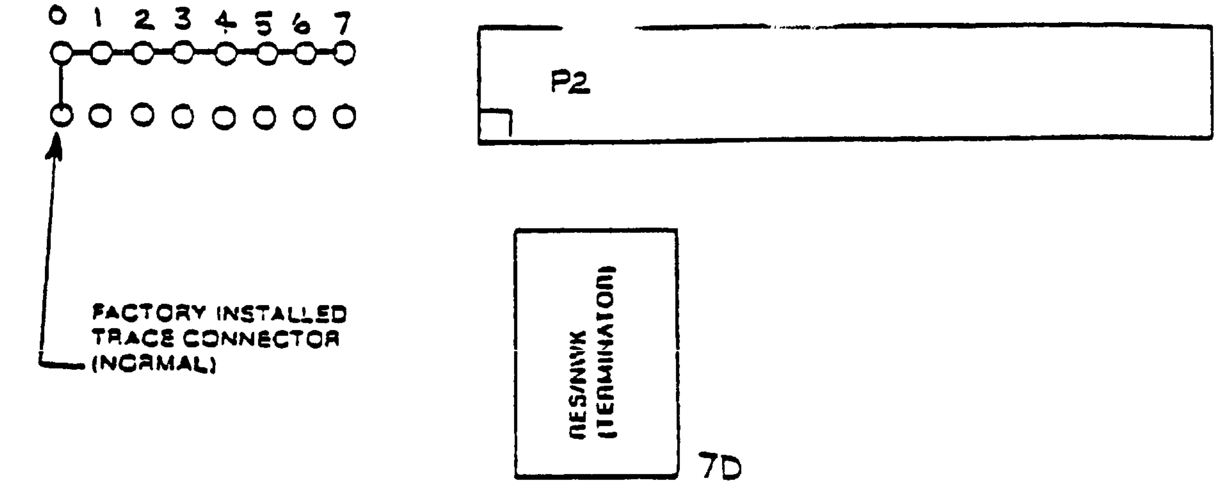

FIGURE 3-3 NORMAL (FACTORY-INSTALLED) ADDRESS JUMPER

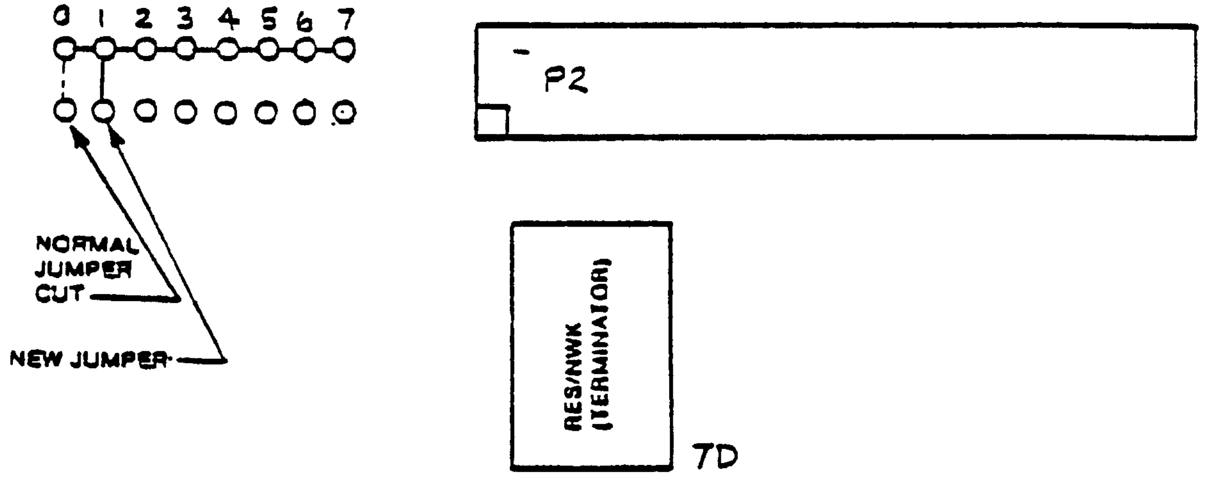

FIGURE 3-4 CHANGED ADDRESS JUMPER (CONTROLLER 1)

CHAPTER 4
THEORY OF OPERATION

GENERAL

This chapter discusses the theory of operation of the S1420 Controller and lays down the guidelines that will enable the user to use the Controller successfully in any number of applications.

4.1.1 Conventions

Signals or lines can be active in either a high or low state. The terms signal, signal lines, and lines mean the same thing. A low state is equivalent to a voltage level of 0.8 volts or less, and a high state is equivalent to a voltage level of 2.4 volts or more. Some texts use the term asserted to mean active. In this manual, only the term active is used; if the term asserted appears, it is only for reference.

4.1.2 Names and Abbreviations

A dash (-), or the lack of one, indicates the active state of a signal. The active state of a signal is that state which is required for a given operation. When a dash is appended to end of a signal name, the signal is active when it is low. When no dash appears at the end of a signal name, the signal is active when it is high. Some signal lines have two so-called active (or significant) states. When the level on the line is high, a particular operation takes place. When the level on the line is low, a different operation takes place. The following examples show the use of these conventions.

BUSY- The signal BUSY- is active when it is at a low level because it has the dash appended.

BUSY The signal BUSY is active at a high level because it does not have the dash appended.

The line C/D (command/data) has a dual purpose; the standard dash (/) indicates duality. It is not apparent what the active states are. The user must look up the definition in the appropriate table.

Other designations used to define signal lines are listed below.

Drv	Driver
Rcvr	Receiver
OC	Open collector
Tri-State	Line has three states: high, low, high impedance
220/330	Line termination (on the controller): 220 Ohms to source voltage/330 Ohms to ground.

Signal Definitions

The following tables list and define the signals that appear on the lines between the host adapter and the Controller.

TABLE 4-1 HOST BUS STATUS SIGNALS

DRV/RCVR	DEFINITION
Drv OC	Input/Output: The controller drives this line. A low level on this line indicates that the Controller is driving the data on the host bus. A high level on this line indicates that the host adapter is driving the data on the host bus. The host adapter monitors this line and uses it to enable and disable it's data bus drivers. This signal is qualified by signal REQ-.

C/D	Drv OC	Command/Data: This signal line indicates whether the information on the data bus consists of command or data bytes. A low means command bytes; a high means data bytes. This signal is qualified by signal REQ-.
BUSY-	Drv OC	Busy: The Controller generates this active low signal in response to the SEL- signal and the address bit (DB0- to DB7-) from the host adapter. The busy signal informs the host adapter the Controller is ready to conduct transactions on the host bus.
MSG-	Drv OC	Message: The Controller sends this active low signal to the host adapter to indicate that the current command has been completed. When MSG- is active, the I/O signal line is always low so that the Controller can drive the bus data lines. This signal is qualified by signal REQ-.

TABLE 4-2 SUMMARY OF HOST BUS STATUS SIGNALS

C/D	MSG-	DEFINITION
Low	High	The Controller receives command from the host adapter.
High	High	The Controller receives data from another source on the SASI bus.
High	High	The Controller sends data over the SASI bus.
Low	High	The Controller sends error status byte to the host adapter.
Low	Low	The Controller informs the host adapter that it has completed the current command.

TABLE 4-3 CONTROLLER-HOST ADAPTER HANDSHAKING

NAME	DRV/RCVR	DEFINITION
REQ-	Drv OC	Request: The Controller sends this active low signal to the host adapter to initiate the controller-host handshaking sequence. This signal qualifies signals I/O, C/D and MSG-.
ACK-	Rcvr, 220/330	Acknowledge: The host adapter generates this active low signal in response to the REQ- signal from the Controller when the host is ready to receive or transmit data. In order to complete the handshake, the host adapter must send an acknowledge (ACK-) in response to each request (REQ-) from the Controller.

TABLE 4-4 HOST BUS CONTROL SIGNALS

<table>
<tr><th>DRV/RCVR</th><th>DEFINITION</th></tr>
<tr><td>Rcvr, 220/330</td><td>Reset: The host adapter sends this active low signal to the Controller to force the Controller to the idle state. After RST- has become active, any Controller status is cleared. RST- also causes the deactivation of all signals to the drives. The time requirements for the RST- signal are as follows:
<table>
<tr><th>Minimum</th><th>Maximum</th></tr>
<tr><td>100 nsec.</td><td>None</td></tr>
</table>
</td></tr>
<tr><td>Rcvr, 220/330</td><td>Select: The host adapter sends this active low signal to the Controller to initiate a command transaction. Along with SEL-, the host adapter must also send an address bit to select the Controller (DBO- for controller 0). The Controller must not be busy. The host adapter must deactivate SEL- before the end of the current command.</td></tr>
</table>

TABLE 4-5 HOST BUS DATA SIGNALS

NAME	DRV/RCVR	DEFINITION
DB7- to DB0-	Tri-State, 220/330	These are the eight data bits (lines) of the host bus (DB0-=LSB). Each line is also used as address bits to select a controller in systems using multiple controllers (see Chapter 3). The normal connection (hardwired on the board) is to DB0- which is the address of controller 0. Any other connection requires cutting the existing trace on the board and adding a jumper. The following list shows the bit assignments.

DB0-	Controller 0
DB1-	Controller 1
DB2-	Controller 2
DB3-	Controller 3
DB4-	Controller 4
DB5-	Controller 5
DB6-	Controller 6
DB7-	Controller 7

BASIC OPERATING CONFIGURATION

The basic operating configuration consists of a host adapter, S1420 Controller, and a 5¼-inch Hard Winchester Disk Drive. Figure 4-1 shows the basic setup. Also shown is an additional, optional hard disk drive and two 5¼-inch Floppy Disk Drives.

The host can be one of a number of computer systems; the host adapter is ar interface between the host's bus and the controller.

4.2.1 Host Bus Signal Termination

Host bus control signals DRIVEN by the host adaptor to the Controller (ACK-, RST- and SEL-) do not require termination on the host end. Components used to drive these signals must be able to sink a minimum of 24mA.

Host bus control signals RECEIVED by the host adaptor from the Controller (I/O, C/D, BUSY-, MSG-, and REQ-) must be terminated by the host adaptor with 220/330 (220 Ohms to source voltage/330 Ohms to ground). Components used to receive these signals should be 7414's (or equivalent hysteresis gates).

The Data Bus signals (DB7- to DB0-) must also be terminated on the host adaptor side with 220/330. Components used to drive the Data Bus must be capable of sinking a minimum of 48mA and those used to receive must be hysteresis gates.

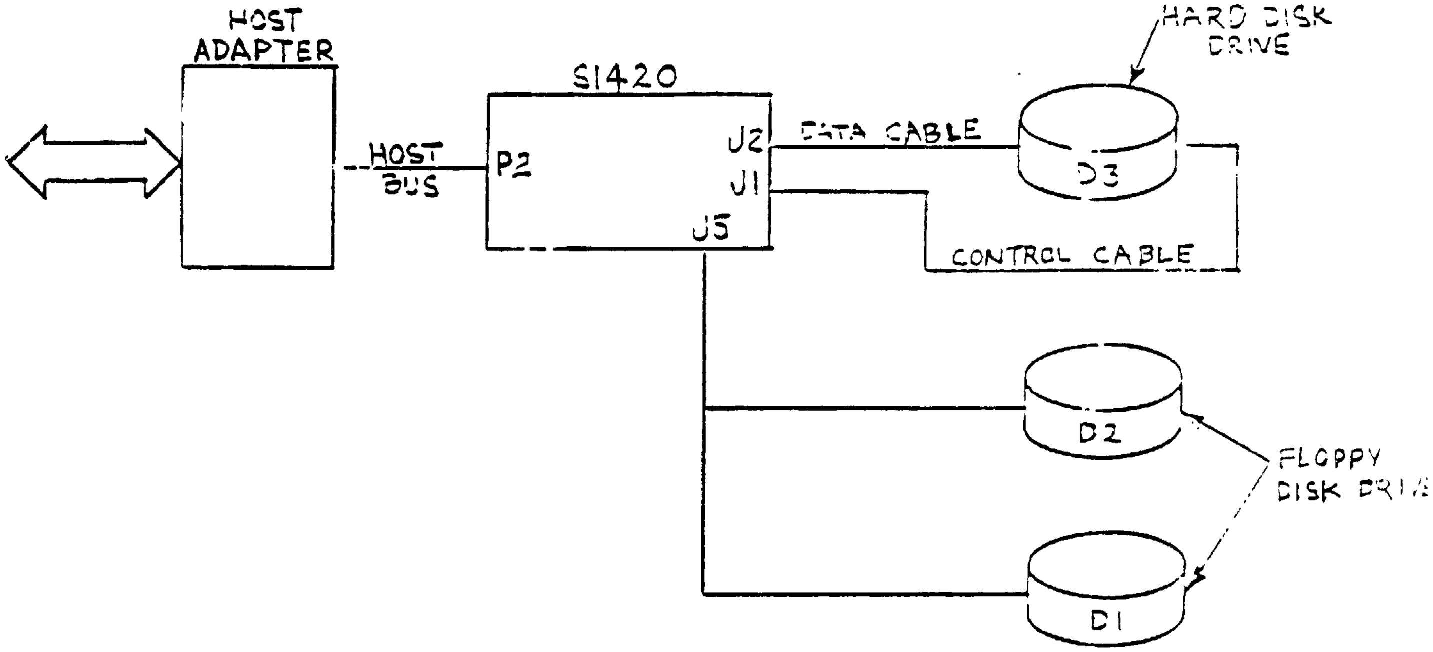

FIGURE 4-1 BASIC OPERATING CONFIGURATION

DETAILED DESCRIPTION

The following paragraphs describe the interaction between the controller and the host adapter.

4.3.1 Controller Selection

Before the host adapter can begin a transaction, it must select the controller. The host adapter selects the controller by activating the SEL- control signal and the address bit of the controller. Any bit, DB0- through DB7-, can be the address bit in a system with multiple controllers (all controllers leave the factory with DB0- connected to the controller's address logic). For this discussion, the controller's address is 0.

The timing diagram in Figure 4-2 shows the basic timing requirements. Upon receiving both the SEL- signal and DBO-, the controller activates the BUSY- signal. As shown in the timing diagram, both SEL- and DBO- must be active (low) before the controller can activate the BUSY- signal. During the selection process, the host has control of the data bus as signified by the deactivation of the I/O line. Selection is complete when BUSY- becomes active. The data bus must be stable 100 nsecs before SEL is activated and remain stable for 100nsec after SEL is deactivated. Note that the Data Bus must be stable before the Select signal is asserted to prevent false selects in a multi-controller environment.

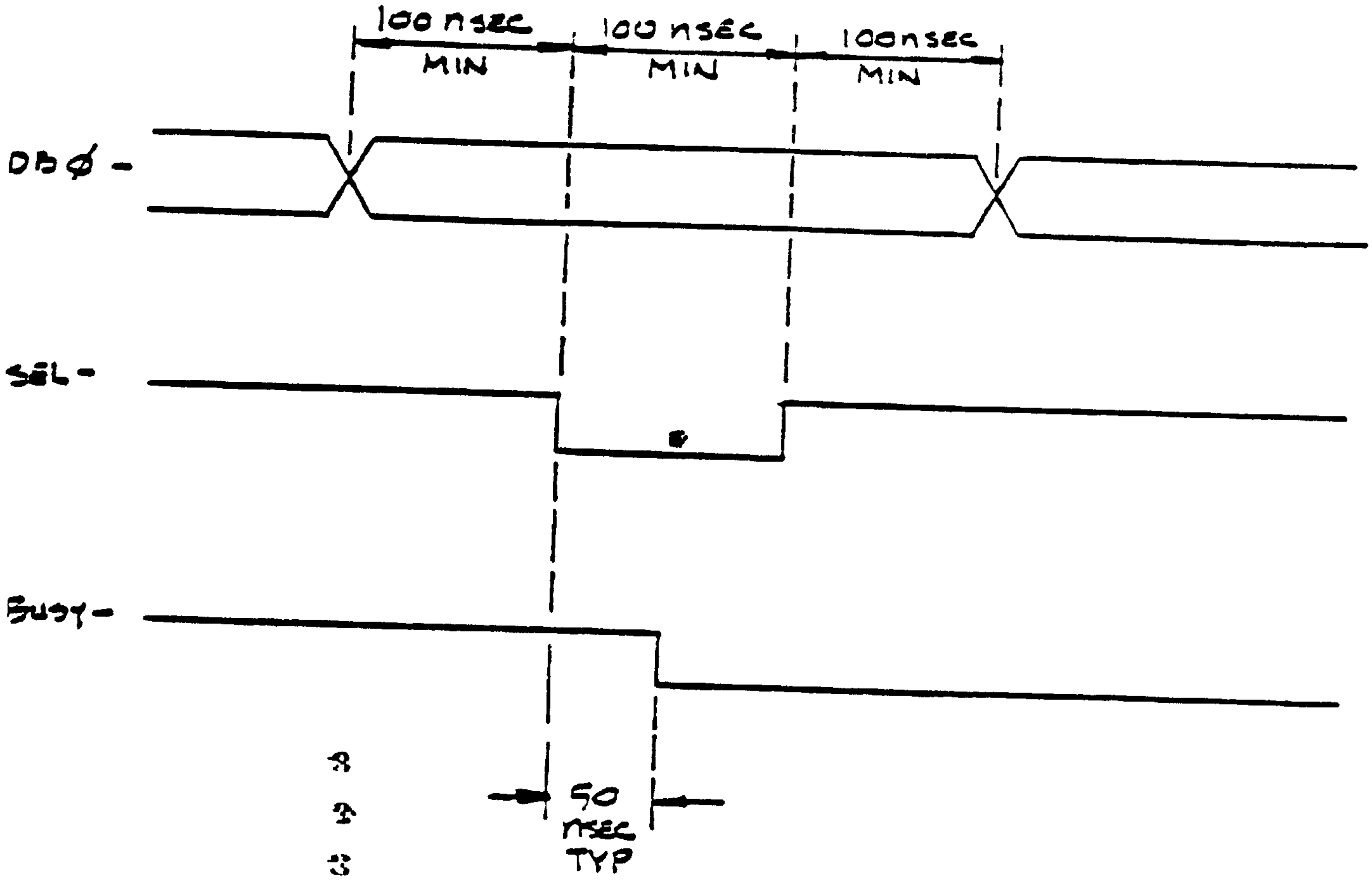

FIGURE 4-2 CONTROLLER SELECT TIMING

Command Mode

The Controller receives commands from the host adapter using a handshaking sequence. The Controller places a low level on the C/D (command/data) line to indicate that it wants a command from the host adapter and places a high level on the I/O line to indicate that the movement of information is from the host adapter to the controller. The MSG- line is high.

The Controller activates the REQ- line within 10 microseconds after signals I/O, C/D and MSG- have been placed at high, low and high levels, respectively. The host adapter responds by activating the ACK- signal when a command byte is ready for the Controller. The command byte placed on the data bus by the host must be stable within 50 nanoseconds after the ACK- signal is activated. The command byte must be held stable until REQ- is deactivated. The host deactivates ACK- after REQ- goes high. This completes the handshake for the first command byte. Each succeeding command byte from the host adapter requires the same complete handshake sequence. See Figure 4-4 for data bus, REQ, and ACK- timing. See Table 4-2 for I/O, C/D and MSG- definition.

Data Transfer

The timing diagrams in Figures 4-3 and 4-4 illustrate the required timing for data transfer. See Table 4-2 for I/O, C/D and MSG- definition.

Status Bytes

Two bytes of status are passed to the host at the end of all commands. The first byte informs the host if any errors occurred during the execution of the command. The second is a zero byte. It signals to the host that the command is complete. Figure 4-3 shows the data bus, REQ- and ACK- timing. See Table 4-2 for I/O, C/D and MSG- definition. Figure 4-5a shows the format of these two bytes.

On the transfer of data from the controller to the host, the data is stable on the bus a minimum of 125 nsec before REQ- becomes active. There is no time limit from REQ- active to ACK- active. After the controller receives ACK-, REQ- will become inactive within 25 to 75 nsec. If the controller has more data to send, it will set REQ- active within 1.2 to 1.7 microsec from REQ- going inactive, if ACK- was set inactive within 1.2 microsec of REQ- going inactive. The controller can not set REQ- active if ACK- is active. If the controller is ready to set REQ- active, but ACK- is active, the controller waits for ACK- to go inactive, then sets REQ- active between 25 and 50 nsec later. There is no time limit for the controller waiting for ACK- to go inactive.

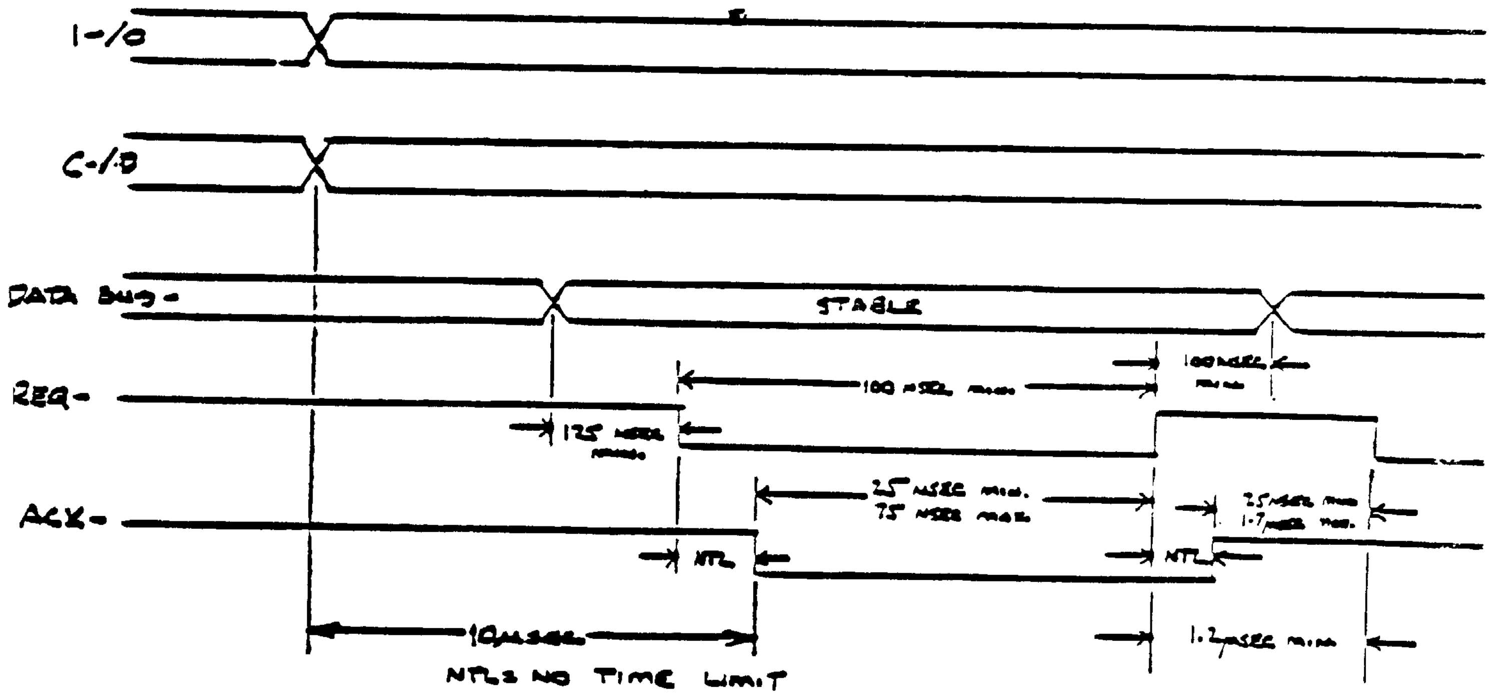

FIGURE 4-3 DATA TRANSFER TO HOST, TIMING

Each data byte transferred from host to the controller starts with the REQ- going active. For REQ- to go active, the host must ensure that ACK- is inactive at the beginning of each byte transfer sequence. After REQ- goes active, the host sets ACK- active while placing a byte of data on the bus. There is no time limit from the time REQ- goes active to ACK-going active. However, there is a time limit of 250 nsec max. for the host to place the data byte on the bus referenced from the ACK- edge. When ACK- goes active, the controller sets REQ- inactive within 1000 nsec max. The host must not change data on the bus until REQ- goes inactive. There is no hold time for the data when REQ- goes inactive. There is no time limit for the host to set ACK- inactive. The controller will not set REQ- active again, for the next byte to transfer until ACK- goes inactive. If ACK- goes inactive, in response to REQ- going inactive, the controller will set REQ- active within 500 nsec. ready to receive the next byte. If the controller is ready to set REQ- active, but ACK- is active, the controller waits for ACK- to go inactive, then sets REQ- between 25 and 50 nsec later.

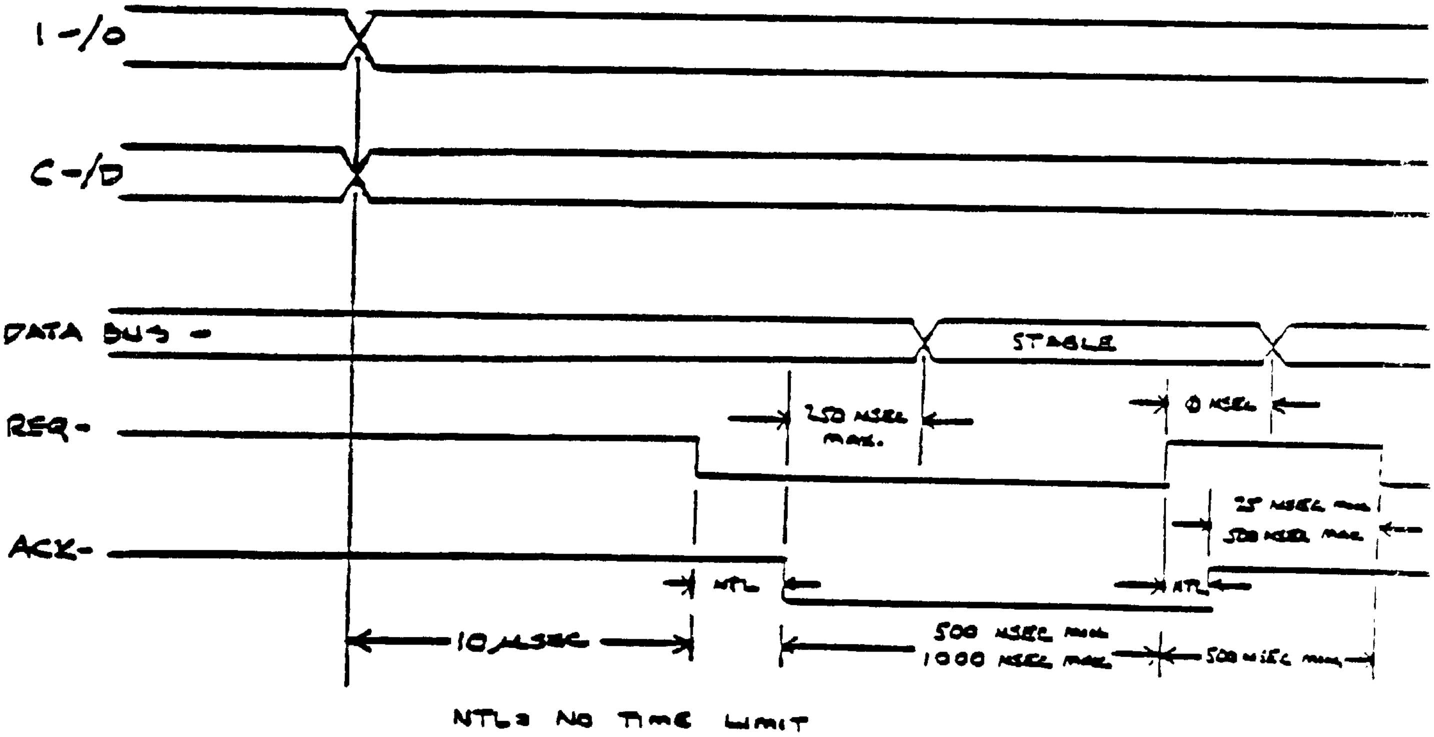

FIGURE 4-4 DATA TRANSFER FROM HOST, TIMING

4.4 PROGRAMMING INFORMATION

The following paragraphs discuss communications between the Controller and host from the point of view of the codes that are passed. The host sends commands to the Controller through the host adapter. The Controller then performs the commands and reports back to the host.

4.5 COMMANDS

The host sends a six-byte block to the Controller to specify the operation. This block is the Device Control Block (DCB). Figure 4-5 shows the composition of the DCB. The list that follows Figure 4-5 defines the bytes that make up the DCB.

Bit	7	6	5	4	3	2	1	0
Byte 0	Command Class					Opcode		
Byte 1		LUN			High Address			
Byte 2		Middle Address						
Byte 3		Low Address						
Byte 4		Interleave or Block Count						
Byte 5		Control Field						

Figure 4-5 Device Control Block (DCB), Format

Byte 0	Bits 7, 6 and 5 identify the class of the command. Bits 4 through 0 contain the opcode of the command.
Byte 1	Bits 6 and 5 identify the logical unit number (LUN). Bits 4 through 0 contain logical address 2. If bit 6 is set to zero bit 5 specifies one of the two hard disks. If bit 6 is set to one, bit 5 specifies one of the two floppy disks.
Byte 2	Bits 7 through 0 contain logical address 1.
Byte 3	Bits 7 through 0 contain logical address 0 (LSB).
Byte 4	Bits 7 through 0 specify the interleave or sector count.
Byte 5	Bits 7 through 0 contain the control field.

Next to Last Status Byte

7	6	5	4	3	2	1	0
0	d	d	0	0	0	ERR	0

Set to zero.

7

When set, an error occurred during the last command execution.

5 Logical unit number of drive, d=0 to 3.

Last Status Byte

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0

Set to zero.

Figure 4-6 Completion Status Bytes

The Control Byte

The control field, byte 5, of the DCB allows the user to select options for different commands. The following list defines the bits of the control byte.

Bit 0-5 Spare. Set to zero for future use.

Bit 6 If one, during a read sector command, the failing sector is not re-read on the next revolution before attempting correction. This bit should be set to zero for normal operation.

Bit 7 Disable the four retries by the Controller on all disk-access commands. Set this bit only during the evaluation of the performance of a disk drive.

Logical Address (High, Middle and Low)

The logical address of the hard disk drive is computed by using the following equation.

Logical Address = ((CYADR-1) * HDCYL + HDADR) * SETRK + SEADR

Where: CYADR = Cylinder Address

HD ADR = Head Address

SEADR = Sector Address

HDCYL = Number of Heads per Cylinder

SETRK = Number of Sectors per Track

Cylinder zero of the disk drive is reserved by the Controller for diagnostic use and to store the disk drive configuration data. Logical address zero maps physically to cylinder 1, Head 0, sector 0. Because of this address shift, the drive appears to be one cylinder smaller than the actual drive capacity. If the host software computes the physical disk address from the logical, remember to add one to the cylinder address to compensate for the address shift. Note that this address translation is completely hidden from the host software. The host software does not have to compensate for this shift between logical and physical addresses, except for user reporting purposes.

The logical address of the floppy disk drive is computed by using the following equation:

Logical Address = (CYLADR * HDCYL + HDADR) * SETRK + SEADR

The definitions are the same as above.

Command Set

The commands fall into eight classes, 0 through 7; only classes 0, 6, and 7 are used. Class 0 command are data, non-data transfer, and status commands. Classes 1 through 5 are reserved; Class 6 are disk-to-disk copy commands; and, Class 7 are diagnostic commands.

Each command is described below. The description includes its class, opcode, and format. When a slash (/) represents a bit position, the slash means that the value of that bit is not important (a don't-care bit).

4.5.3.1 Test Drive Ready (Class 0, Opcode 00)

This command selects a particular drive and verifies that the drive is ready. The following diagram shows the format of the device control block for this command.

d = drive, 0 to 3

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0
0	d	d	/	/	/	/	/
/	/	/	/	/	/	/	/
/	/	/	/	/	/	/	/
/	/	/	/	/	/	/	/
/	/	/	/	/	/	/	/

Note that the 5¼" floppy drive will always show ready since the drive does not return a ready signal.

4.5.3.2 Recalibrate (Class 0, Opcode 01)

This command positions the read/write (R/W) arm to track 00.

d = drive, 0 to 3
r = retries

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	1
0	d	d	/	/	/	/	/
/	/	/	/	/	/	/	/
/	/	/	/	/	/	/	/
/	/	/	/	/	/	/	/
r	0	0	0	0	0	0	0

Reserved (Class 0, Opcode 02)

This opcode is not used.

Request Sense Status (Class 0, Opcode 03)

The host must send this command immediately after it detects an error. The command causes the Controller to return four bytes of drive and Controller status; the formats of these four bytes are shown after the DCB. When an error occurs on a multiple sector data transfer, (read or write), the Request Sense Status command returns the logical address of the failing sector in bytes 1, 2 and 3. If the Request Sense Status command is issued after any of the Format commands or the Check Track Format command, then the logical address returned by the controller points to one sector beyond the last track formatted or checked if there was no error. If there was an error, then the logical address returned points to the track in error. The tables that follow the formats list the error codes.

d = drive, 0 to 3

Bit	7	6	5	4	3	2	1	0
Byte 0	0	0	0	0	0	0	1	1
Byte 1	0	d	d	/	/	/	/	/
Byte 2	/	/	/	/	/	/	/	/
Byte 3	/	/	/	/	/	/	/	/
Byte 4	/	/	/	/	/	/	/	/
Byte 5	/	/	/	/	/	/	/	/

Sense Bytes

Bit	7	6	5	4	3	2	1	0
Byte 0				SEE BELOW				

Bits 0-3	Error Code
Bits 4-5	Error Type
Bit 6	Spare, set to zero
Bit 7	Address valid, when set

The address valid bit in the error code byte (bit 7) is relevant only when the previous command required a logical block address; in which case it is always returned as a one otherwise it is set to zero. For instance, if a Recalibrate command is followed immediately by a Request Sense Status command, the address valid bit would be returned as zero since this command does not require a logical block address to be passed in its DCB.

Bit	7	6	5	4	3	2	1	0
Byte 1	0	d	d		High Address			
Byte 2		Middle Address						
Byte 3		Low Address						

d = drive, 0 to 3

DEFINITION

No Error Occurred. This code is always returned if no error had occurred during the previous command.

No Index Signal from the Drive. This occurs on the hard disk during and data transfer or format command if a normal drive select occurs, the drive is ready, but no index signal is detected from the drive within two revolutions of the disk.

No Seek Complete Signal from the Drive. This error occurs on non-buffered seek processing if the Controller does not receive the Seek Complete Signal from the Drive within one second following the last step pulse.

Write Fault Signal Received from the Drive. This error occurs if the controller detects an active write fault signal from the disk drive either at the completion of a sector data transfer or initially after a successful drive select and the drive indicates ready.

Disk Drive Not Ready. This error occurs if the controller fails to receive the select signal from the drive, or the drive indicates not ready after selection.

Track 00 Not Found. After stepping the drive 200 more steps than the number of cylinders on the hard disk, or 77 steps on the floppy during a recalibrate command, the Track 00 Signal was not received from the drive.

Disk Drive Still Seeking. This status is returned in response to a test drive ready command if a buffered step seek was issued to a hard disk drive and the drive has not returned the seek complete signal. Software must time the seek to insure no system hang occurs if the drive fails to return the seek complete signal. Treat a seek incomplete condition the same as error code 02.

Controller Not Initialized. This status is returned if the controller is requested to execute a drive command, but the controller has not received an initialize Format Command for this drive, or is unable to retrieve the initialization, parameters from the hard disk, or the floppy disk parameters from the hard disk 0.

-7 Type 1 Error Codes, Controller

DEFINITION

ID Read Error. During a data transfer or format command, address marks were detected, but the target sector was not found and an ECC or CRC error occurred on one or more ID fields.

Media defects may be overcome by deleting the defective sectors from system use or assigning an alternate track.

Uncorrectable Data Error in the Data Field. The controller detected a data error on the hard disk that could not be corrected using ECC, or the controller detected a CRC error on floppy.

Media defects may be overcome by deleting the defective sectors from system use or assigning an alternate track.

Sector Address Mark Not Found. The controller did not detect an address mark (AM) from the drive within its timing window. An address mark is a special recording pattern preceding the ID field of a sector. The AM is only written at format time. The AM tells the controller where new sector starts. The error may occur during any data transfer or format commands. The error may mean that no address marks were detected on the track, or the target sector address mark was not detected.

Media defects may be overcome by deleting the defective sectors from system use or assigning an alternate track.

A Write Protect Error. A Write operation was attempted on a write protected floppy disk.

Target Sector Not Found. The target sector was not located within two revolutions of the disk. This error usually occurs when there is a media defect in the address mark field of the target sector.

Seek Error. After a seek, the target disk address did not match the address read from the disk. Either the cylinder or head bytes did not match.

Format Track Not Complete. The FDC chip failed to completely format a track on the floppy disk.

FDC Busy. The Floppy Disk Controller (FDC) was busy when it should have been idle, and the controller was unable to clear the condition.

Correctable Data Error. The controller detected a media error on the hard disk while reading that was corrected by ECC. This error code informs the host software that error correction has taken place. This is the only error where the data is passed to the host before returning the error status.

Track or Sector is Flagged Bad. The last data transfer command encountered a track that had been flagged defective using the Format Bad Track Command on the hard disk. On the floppy, a sector containing a deleted data mark was read. Host software is responsible for insuring that deleted tracks are never accessed.

Format Error. During execution of a check track command, the controller detected an unformatted track, the wrong interleave on disk, or an ID ECC error on at least one sector.

FDC Lost Data Error. The FDC had either a data overrun or underrun condition during the last command.

Controller Detected a Direct Access to an Alternate Track. A track that has the alternate track flag set in the ID has been directly accessed by the host on the hard disk, instead of coming from the defective track that is assigned to this alternate track. Care must be used in software to insure that the alternate track area is not accessed directly during data transfer commands.

The Designated Alternate Track is already assigned to another Defective Track. Host software has attempted to assign an alternate track to replace a defective track, but the alternate had previously been assigned to a defective track. If an alternate track is no longer needed, the host software must reformat the track using the FORMAT TRACK command before attempting to reassign the track again.

Assigned Alternate Track Not Found. A defective track has been assigned an alternate track, but the alternate track does not have the alternate track bit set in the ID field. This may be caused by reformatting the alternate track with the format track command without reprocessing the defective track.

The Alternate and Defective Track Addresses Point to the Same Track. Host software has attempted to assign a defective track to itself. That is not allowed in this alternate track scheme.

DEFINITION

Invalid Command: The controller has received an invalid command from the host.

Illegal Disk Address: The controller detected an address that is beyond the maximum range.

Illegal Parameter: The controller detected an option, or combination of options that are illegal for this device.

Copy Completion Mismatch: During Copy operation the last section written to the target drive was partly but not completely filled with data from the source drive.

RAM Error: The controller detected a data error during the RAM sector-buffer diagnostic.

Program Memory Checksum Error: During its internal diagnostic, the controller detected a program-memory checksum error. This is caused by a defect in the program memory chip of the controller.

ECC Polynomial Error: During the controller's internal diagnostic, the hardware ECC generator failed its test.

The following is a summary of the error codes returned as the result of the Request Sense Status command.

NOTE: The address valid bit (bit 7) may or may not be set and is not included here for clarity.

Error Code (hex)	Meaning.
00	No error detected (command completed ok).
01	No index detected from disk drive.
02	No seek complete from disk drive
03	Write fault from disk drive
04	Drive not ready or not selected.
05	Not used.
06	Track 00 not found.
07	Not used.
08	Disk drive still seeking.
09	Not used.
0A	Controller not Initialized.
0B-0F	Not used.
10	ID field read error.
11	Uncorrectable data error.
12	Address mark not found.
13	Write protect error.
14	Target sector not found.
15	Seek error.
16	Format track not complete.
17	FDC busy error.
18	Correctable data error.
19	Bad track flag detected.
1A	Format error.
1B	Not used.
1C	Direct access to an alternate track.
1D	Alternate already assigned.
1E	Alternate not found.
1F	Alternate assigned to defective track.
20	Invalid command.
21	Illegal disk address.
22	Illegal parameter.
23	Copy completion mismatch.
24-2F	Not used.
30	Ram diagnostic failure.
31	Program memory checksum error.
32	ECC diagnostic failure.
33-3F	Not used.

5 Format Drive (Class 0, Opcode 04)

This command formats all sectors with ID and data fields according to the selected interleave factor. Formatting begins with the first sector of the track specified by the starting address of the DCB. The controller will format all tracks from the starting track to the end of the disk. If the b bit is zero, the data fields will contain a 6C for the hard disk. The data field is formatted with an E5 for the floppy FM format, and a 40 for the floppy MFM format. It the b bit is one, the data already contained in the buffer is used to format the hard disk. The b bit is ignored for the floppy format. If the T bit in the initialize format command is set to one, the hard disk format will leave a 300 microsecond gap before index. This format is to be used for imbedded servo field drives. If the T bit is reset, the entire track is used for formatting the hard disk. This bit is ignored for the floppy format. The format command does not read verify the sector.

Following the format of the hard disk, the drive parameters passed in the Initialize Format Command are written and verified on the maintenance cylinder (cylinder 0) of the hard disk. Both the hard disk and floppy disk parameters are stored.

d = drive, 0 to 3

r = retries

b = if set, use buffer contents

7	6	5	4	3	2	1
0	0	0	0	0	1	0
0	d	d		High Address		
	Middle Address					
	Low Address					
0	0	0		Interleave		
r	0	b	0	0	0	0

Interleave (See Section 4.10)

1 to n-1 for n sectors per track.

5 Check Track Format (Class 0, Opcode 05)

This command checks the format on the specified track for correct ID and interleave on the hard disk only. The command does not read the data field.

d = drive, 0 or 1
r = retries

7	6	5	4	3	2	1	0
0	0	0	0	0	1	0	1
0	0	d		High Address			
	Middle Address						
	Low Address						
0	0	0		Interleave			
r	0	0	0	0	0	0	0

Interleave: 1 to 31 for 256 byte sectors.
1 to 16 for 512 byte sectors.

Format Tracks (Class 0, Opcode 06)

This command formats the number of tracks specified in the two data bytes passed following the DCB. The format operation starts the first sector of the track specified by the disk address bytes in the DCB. The controller recalibrates the drive, seeks to the starting track, and begins the format operation. Formatting continues on a track by track basis until the track count is exhausted or the end of the disk is reached. If the track count exceeds the disk capacity, the controller returns an illegal address error after formatting the last track on the drive. The data field is filled with the default data pattern 6C Hex on the hard disk. If bit 5 of byte 5 is set to one, the data field will be taken as is from the buffer for the hard disk. The data fields on the floppy are formatted with E5 for FM and 40 for MFM data. If the T bit in the initialize format command is set to one, the hard disk format will leave a 300 microsecond gap before index to allow for the imbedded servo area if the disk requires it. If the T bit is zero, the entire track is used.

If the two track count data bytes contain zero, the initialization data will be written on the reserved cylinder (Cylinder 0). No tracks are formatted. This allows changing the initialization parameters for the drive without reformatting the drive. Issue the Initialize Format Command, followed by the Format Tracks Command with the track count set to zero to permanently update the disk drive parameters.

d = drive, 0 or 3
r = retries
b = use data already in the buffer
(T) s = imbedded servo hard disk

7	6	5	4	3	2	1	0
0	0	0	0	1	0	0	0
0	0	d		High Address			
	Middle Address						
	Low Address						
	Block Count						
r	0	b	S (T)	0	0	0	0

The two byte track count is transferred with the most significant byte first.

Format Bad Track Class (Class 0, Opcode 07)

This command formats the specified track and sets the bad-sector flag in the ID fields on the hard disk. It does not write the data fields. If the track is accessed with normal data transfer commands, an access to defective track (Error Code 19 Hex) is returned.

d = drive, 0 or 1
r = retries

7	6	5	4	3	2	1	0
0	0	0	0	0	1	1	1
0	0	d		High Address			
	Middle Address						
	Low Address						
0	0	0		Interleave			
r	0	0	0	0	0	0	0

Interleave:
1 to 31 for 256 sectors
1 to 16 for 512 sectors

Read (Class 0, Opcode 08)

This command reads the specified number of sectors, starting with the initial sector address contained in the DCB. Each sector of data is 128, 256 or 512 bytes. The number of bytes per sector is set by the Initialize Format command. If bit 6 of byte 5 is reset, the Controller will reread a defective sector before attempting error correction on the hard disk. If the reread occurs without error, or the error is correctable, the Controller will pass the data to the host and not report an error. If bit 6 of byte 5 is set, the controller attempts error correction without a reread of the defective sector. If the error is correctable, the Controller passes the data to the host, then terminates the operation with a correctable data error. If the error is uncorrectable, in either case, the operation is terminated with an uncorrectable data error and the data is not returned to the host.

d = drive, 0 to 3
r = retries
a = retry option on data ECC error

7	6	5	4	3	2	1	0
0	0	0	0	1	0	0	0
0	d	d		High Address			
	Middle Address						
	Low Address						
	Block Count						
r	a	0	0	0	0	0	0

0 Read Verify (Class 0, Opcode 09)

This command executes the same as the read data command, except that no data is passed to the host. This command may be used to verify data integrity without having to transfer the data to the host. If bit 6 of byte 5 of the DCB is reset, the Controller will reread a defective sector before attempting error correction. If no data error occurs on the reread, the verify will continue and no error will be reported. If the error occurs again, error correction is applied, and the correctable or uncorrectable data error returned to the host. If bit 6 of byte 5 is set, error correction is applied without a reread step, and the error is returned to the host.

d = drive, 0 or 1

r = retries

a = retry option on data ECC error

7	6	5	4	3	2	1	0
0	0	0	0	1	0	0	1
0	d	d		High Address			
	Middle Address						
	Low Address						
	Block Count						
r	a	0	0	0	0	0	0

4.5.3.11 Write (Class 0, Opcode 0A)

This command writes the specified number of sectors, starting with the initial sector address contained in the DCB. Each sector of data can be 128, 256 or 512 bytes long. The sector size is determined at format time.

d = drive, 0 to 3
r = retries

Bit	7	6	5	4	3	2	1	0
Byte 0	0	0	0	0	1	0	1	0
Byte 1	0	d	d		High Address			
Byte 2		Middle Address						
Byte 3		Low Address						
Byte 4		Block Count						
Byte 5	r	0	0	0	0	0	0	0

4.5.3.12 Seek (Class 0, Opcode 0B)

This command initiates a seek to the track specified in the DCB. The drive must be formatted.

d = drive, 0 to 3
r = retries

Bit	7	6	5	4	3	2	1	0
Byte 0	0	0	0	0	1	0	1	1
Byte 1	0	d	d		High Address			
Byte 2		Middle Address						
Byte 3		Low Address						
Byte 4	/	/	/	/	/	/	/	/
Byte 5	r	0	0	0	0	0	0	0

4.5.3.13 Reserved (Class 0, Opcode 0C)

4.5.3.14 Read ECC Burst Error Length (Class 0, Opcode 0D)

This command transfers one byte to the host. This byte contains the value of the ECC burst length that the controller detected during the last Read command on the hard disk. This byte is valid only after a correctable ECC data error, type 1, code 8.

Bit	7	6	5	4	3	2	1	0
Byte 0	0	0	0	0	1	1	0	1
Byte 1	/	/	/	/	/	/	/	/
Byte 2	/	/	/	/	/	/	/	/
Byte 3	/	/	/	/	/	/	/	/
Byte 4	/	/	/	/	/	/	/	/
Byte 5	/	/	/	/	/	/	/	/

4.5.3.15 Format Alternate Track (Class 0, Opcode 0E)

This command assigns an alternate track to a defective track on the hard disk. After the alternate track is assigned, the Controller will automatically move all normal read/write operations from the defective to the alternate track. This change is transparent to the host during normal read and write operations.

Format Alternate Track will format all sectors of the defective track with a physical disk address of the alternate track. The alternate track is formatted to identify it as an alternate track.

d = drive, 0 or 1

r = retries

b = use buffer data

s = if set for data field hard disk has imbedded servo field

Bit	7	6	5	4	3	2	1	0
Byte 0	0	0	0	0	1	1	1	0
Byte 1	0	0	d		High Address			
Byte 2		Middle Address						
Byte 3		Low Address						
Byte 4	/	/	/	/	/	/	/	/
Byte 5	r	0	b	s	0	0	0	0

The logical address in the command DCB points to the defective track. the address of the alternate track is passed as three data bytes following the command block. The address is passed to the Controller MSB first, followed by the MID and LSB in order. Both addresses are used as track addresses, and formatting begins at sector zero of each track.

If bit 5 of Byte 5 is set to a one, the controller uses the data already in the buffer as the data bytes instead of the 6C Hex default data pattern.

After receiving the command block and the alternate address data bytes, the Controller does the following to assign the alternate track:

A) Seeks to the "Alternate Assigned Track" and verifies that the track is not already assigned as an alternate or not flagged as a defective track. If either of the above conditions is true, the operation is aborted and an error code 1D hex returned.

This means that the host is attempting to assign an alternate track that has already been assigned or has been flagged defective.

If the track is unassigned, the Controller formats the track as an assigned alternate track.

Seeks to the "Defective Track" and formats the track as a defective track with the alternate track assigned.

All data fields on both tracks are destroyed by the format operation.

on host system use of the Format Alternate command:

The alternate tracks are not available for system use. It is the responsibility of the host to reserve the alternate track area on the disk, and to prevent that area from direct access by the users. The number of spare tracks to allocate is normally specified by the drive manufacturer. Generally, this is one spare allocated per 100 tracks on the disk.

The Controller must be initialized to access the whole drive, including the alternate track area.

To initialize a disk, the following procedure should be followed:

1) Format the entire disk, including the spare track area.
2) Verify the disk with controller retries disabled. Form a list of media defects.
3) For each media defect, assign an alternate track. To be safe, include the list of defective tracks provided by the drive manufacturer.

In system operation, the alternate tracks are invisible to the host. The Controller will automatically seek to the assigned alternate track when the host accesses the flagged defective track. "Consecutive" accesses to a flagged track does not cause the Controller to seek back to the defective track and return to the alternate track. The Controller will maintain position on the alternate track as long as the host accesses the same defective track.

4.5.3.16 Write Buffer (Class 0, Opcode 0F)

This command is used to fill the Controller buffer with a data pattern from the host. This command can be used with the read buffer command to test buffer operation, or to provide a non-standard data pattern to be written into the data fields by the various format commands.

Bit	7	6	5	4	3	2	1	0
Byte 0	0	0	0	0	1	1	1	1
Byte 1	/	/	/	/	/	/	/	/
Byte 2	/	/	/	/	/	/	/	/
Byte 3	/	/	/	/	/	/	/	/
Byte 4	/	/	/	/	/	/	/	/
Byte 5	/	/	/	/	/	/	/	/

The command accepts either 256 or 512 bytes. The Controller must be initialized with the drive parameters for hard disk drive 0 before this command is issued so that the Controller knows if the block size is 256 or 512 bytes. If no drive is attached to the Controller, the host must issue the Initialize Format command for hard disk drive 0 prior to issuing this command.

4.5.3.17 Read Buffer (Class 0, Opcode 10)

This command is used to retrieve data from the Controller's buffer. This command can be used in conjunction with the Write Buffer command to test the data buffer, and to retrieve the data from a sector that contains an uncorrectable data error.

	7	6	5	4	3	2	1	0
	0	0	0	1	0	0	0	0
	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/

This command accepts either 256 or 512 bytes of data. The Controller must be initialized with hard disk drive parameters for drive 0 before the Read Buffer command is issued so that the Controller knows if the block size is 256 or 512 bytes. If no drive is attached to the Controller, the host must issue the Intialize Format command for drive 0 prior to issuing this command.

8 Initialize Format (Class 0, Opcode 11)

This command allows the user to set up the Controller for various disk drives of different configuration. The host specifies all the necessary parameters to enable the Controller to control the drive. This command must be issued prior to the drive format command. After the hard disk drive is formatted, the Controller will store these parameters on the maintenance cylinder (cylinder 0) of the drive. Both the hard and floppy disk parameters are stored on hard disk drive. Following subsequent Controller resets, the Controller will fetch initialization data from the maintenance cylinder of the drive. This means that the host software does not issue this command during normal use of the system, but only under a special format utility program.

The Controller does not have any default initialization parameters at reset time. If the Controller cannot read the initialization parameters from the drive, this command must be issued before any command that accesses the drive. Failure to adhere to this rule will result in a "Controller not initialized" error (Error Code 0A Hex).

d = drive, 0 to 3

7	6	5	4	3	2	1	0
0	0	0	1	0	0	0	1
0	d	d	/	/	/	/	/
/	/	/	/	/	/	/	/
/	/	/	/	/	/	/	/
/	/	/	/	/	/	/	/
/	/	/	/	/	/	/	/

After sending the command (DCB) to the Controller, the host must follow with a ten byte data block. This block provides all the initialization parameters to the Controller. The hard disk configuration block is:

7	6	5	4	3	2	1	0
C	C	C	C	C	C	C	C
C	C	C	C	C	C	C	C
0	0	0	0	0	H	H	H
S	S	S	S	0	0	0	T
0	0	0	0	0	0	D	D
W	W	W	W	W	W	W	W
W	W	W	W	W	W	W	W
P	P	P	P	P	P	P	P
P	P	P	P	P	P	P	P
0	0	0	0	E	E	E	E

Where:

C = Number of Cylinders (Most Significant byte first)

H = Number of Heads

S = Step Option

0000 - 3 msec step

0001 - 15 usec buffered step

0010 - 30 usec buffered step

0011 - 70 usec buffered step

0100 - 200 usec buffered step

T = Encoded Disk Drive Type

0 = Standard drive

1 = Imbedded servo fixed drive

D = Data Field Size

01 = 256 data bytes per sector (32 sectors per track)

10 = 512 data bytes per sector (17 sectors per track)

W = Reduced Write Current Cylinder

P = Write Precompensation Cylinder

E = Maximum burst error correction length, up to 11 bits

The number of cylinders, number of heads, drive type, step option, reduced write and write precompensation is obtained from the disk drive manufacturer's specification. The data field size and maximum burst error length are selected by the user. The ECC hardware in the Controller can correct a single burst error of 11 bits or less. If E is set to less than 11 bits, the Controller will flag as uncorrectable any error whose length exceeds E bits, even though the hardware has the capability to correct 11 bits. The host software may use this feature to provide an early warning indicator of growing defects on the drive. The Controller will terminate with an "Illegal Parameter" error (Error 22 Hex) if it detects an invalid parameter or invalid combination of parameters.

The Controller will determine the number of sectors per track from the sector data field size. A data field size of 256 bytes will have 32 sectors per track, while a data field size of 512 bytes will have 17 sectors per track.

The floppy configuration block is:

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0
C	C	C	C	C	C	C	C
0	0	0	0	0	0	H	H
S	S	S	S	0	0	F	F
0	0	0	0	0	0	D	D
0	0	0	0	T	T	T	T
M	M	M	M	M	M	M	M
0	L	L	L	L	L	L	L
U	U	U	U	U	U	U	U
0	0	0	0	0	0	0	S

Where:

C = Number of Cylinders (1 to 255)

H = Number of Heads (1 or 2)

S = Floppy Step Option (0 to 15)

(2 to 32 milliseconds per step in increments of 2 milliseconds)

F = Format Density

01 - FM single density on all tracks (128 byte only)

10 - FM single density on track zero, MFM double density on all other tracks (256, 512 byte only)

11 - MFM double density on all tracks (256, 512 bytes only)

D = Data Field Size in Bytes

01 = 128 bytes (FM only)

10 = 256 bytes (combination or MFM only)

11 = 512 bytes (combination and MFM only)

T = Head Unload Time After a Read or Write

(16 - 240 ms in 16 ms increments)

M = Motor Start Time in tens of millseconds (0 = 2.56 seconds, 1 = 0.01 seconds..., FF = 2.55 seconds)

L = Head Load Time in the FDP
(2 to 254 ms in 2 ms increments)

U = Motor on time after command completion in tenths of seconds (0 = 25.6 seconds, 1 = 0.1 seconds..., FF = 2.55 seconds)

S = Sectors/Track for 512 bytes/sector only (0 = 8 sectors/track, 1 = 9 sectors/track)

Only certain combinations of parameters are legal. An illegal combination will result in an error, code 22 Hex (Invalid Parameter) returned in the Sense command. For example, the 128 byte data size can only be used with the FM single density on all tracks.

The number of sectors per track on the floppy is fixed by the data field size and format density options as shown in table.

TABLE

DATA FIELD	**FORMAT (SECTORS/TRACK)**	
SIZE (BYTES)	**FM**	**MFM**
128	16	-
256	16*	16
512	8*	8
512	9*	9

* Only applies to track 0 if Format Density two (FM single density on track 00, MFM double density on all other tracks) is chosen. In this case, the sectors on track 00 will have ½ the number of data field bytes per sector and be recorded in FM.

4.5.3.19 Read Initialize Data (Class 0, Opcode 12)

This command permits the host software to determine the initialization parameters set previously by the Initialize Format command and recorded on the maintenance cylinder of the drive. The data format is identical to that of the Initialize Format command.

Bit	7	6	5	4	3	2	1	0
Byte 0	0	0	0	1	0	0	1	0
Byte 1	0	d	d	/	/	/	/	/
Byte 2	/	/	/	/	/	/	/	/
Byte 3	/	/	/	/	/	/	/	/
Byte 4	/	/	/	/	/	/	/	/
Byte 5	/	/	/	/	/	/	/	/

After sending the command (DCB) to the Controller, the host must read a ten byte data block. This block provides all the initialization parameters to the Controller in the same format passed in the initialize format command.

4.5.3.20 Copy (Class 6, Opcode 00)

This command will copy data from one disk to another without passing the data through the host computer. This command allows a copy between any two devices attached to the controller. The parameters specified in the 6 DCB bytes specify the source drive (the drive to read data from).

d = drive, 0 to 3

r = retries

a = retry option in ECC error (hard disk)

7	6	5	4	3	2	1	0
0	1	1	0	0	0	0	0
0	d	d		High Address			
	Middle Address						
	Low Address						
/	/	/	/	/	/	/	/
r	a	0	0	0	0	0	0

The first 6 bytes of the 9 data bytes specify the DCB of the target drive (the drive to write data to). The last 3 bytes specify the block count of the source drive. The block count is passed most significant byte first, followed by the middle and least significant bytes in order.

d = drive, 0 to 3

r = retries

7	6	5	4	3	2	1	0
/	/	/	/	/	/	/	/
0	d	d		High Address			
	Middle Address						
	Low Address						
/	/	/	/	/	/	/	/
r	0	0	0	0	0	0	0
	High Block Count						
	Middle Block Count						
	Low Block Count						

The controller will copy each sector until the sector count specified in data bytes 6 to 8 is exhausted or the address of the source or destination drive exceeds the drive size. If the address exceeds the drive size, an illegal address error (Code 21 Hex) will be returned in a Request Sense command.

4.5.3.21 RAM Diagnostic (Class 7, Opcode 00)

This command performs a data pattern test on the RAM buffer.

Bit	7	6	5	4	3	2	1	0
Byte 0	1	1	1	0	0	0	0	0
Byte 1	/	/	/	/	/	/	/	/
Byte 2	/	/	/	/	/	/	/	/
Byte 3	/	/	/	/	/	/	/	/
Byte 4	/	/	/	/	/	/	/	/
Byte 5	/	/	/	/	/	/	/	/

This command does a walking 1 and walking 0 pattern test of its internal RAM buffer.

4.5.3.22 Reserved (Class 7, Opcode 01)

This opcode is not used.

4.5.3.23 Reserved (class 7, Opcode 02)

This opcode is not used.

4.5.3.24 Drive Diagnostic (Class 7, Opcode 03)

This command tests both the drive and the drive-to-controller interface. The controller sends recalibrate and seek commands to the selected drive and verifies sector 0 of all the ID fields. It is assumed that the disk has been previously formatted. On the hard disk, deleted tracks are ignored, and the alternate tracks assigned to defective tracks are checked. After drive verification, one sector on each head of the maintenance cylinder (cylinder 0) is written and read back to insure proper operation of the drive (Hard disk only).

d = drive, 0 to 3

Bit	7	6	5	4	3	2	1	0
Byte 0	1	1	1	0	0	0	1	1
Byte 1	0	d	d	/	/	/	/	/
Byte 2	/	/	/	/	/	/	/	/
Byte 3	/	/	/	/	/	/	/	/
Byte 4	/	/	/	/	/	/	/	/
Byte 5	r	0	0	0	0	0	0	0

4.5.3.25 Controller Internal Diagnostics (Class 7, Opcode 04)

This command causes the controller to perform a self-test. The controller checks its internal processor, data buffers, ECC circuitry, and the checksum of the program memory. The controller does not access the disk drive.

Bit	7	6	5	4	3	2	1	0
Byte 0	1	1	1	0	0	1	0	0
Byte 1	/	/	/	/	/	/	/	/
Byte 2	/	/	/	/	/	/	/	/
Byte 3	/	/	/	/	/	/	/	/
Byte 4	/	/	/	/	/	/	/	/
Byte 5	/	/	/	/	/	/	/	/

4.5.3.25 Read Long (Class 7, Opcode 05)

This command transfers the target sector and four bytes of data ECC to the host. If an ECC error occurs during the read, the controller does not attempt to correct the data field. This command is useful in recovering data from a sector that contains an uncorrectable ECC error. It is also useful as a diagnostic tool to check for proper operation of the ECC error detect and correction algorithm on the hard disk.

d = drive, 0 or 1
r = retries

Bit	7	6	5	4	3	2	1	0
Byte 0	1	1	1	0	0	1	0	1
Byte 1	0	0	d		High Address			
Byte 2		Middle Address						
Byte 3		Low Address						
Byte 4		Block Count						
Byte 5	r	0	0	0	0	0	0	0

4.5.3.27 Write Long (Class 7, Opcode 06)

This command transfers a sector of data and four appended ECC bytes to the disk drive. During this write operation, the host supplies the four ECC bytes instead of the usual hardware-generated ECC bytes. This command is useful to test for proper operation of the ECC error defect and correction algorithm on the hard disk.

d = drive, 0 or 1
r = retries

Bit	7	6	5	4	3	2	1	0
Byte 0	1	1	1	0	0	1	1	0
Byte 1	0	0	d		High Address			
Byte 2		Middle Address						
Byte 3		Low Address						
Byte 4	0	Block Count						
Byte 5	r	0	0	0	0	0	0	0

SECTOR FORMAT

Figure 4-9 lists the format of a sector on the hard disk, including the field names, length, and use. Table 4-10 and 4-11 similarly lists the format of a sector on the floppy disk.

TABLE 4-9 HARD DISK SECTOR FIELD DESCRIPTION

FIELD	BYTES	FIELD DESCRIPTION
GAP1	6	Zero Byte Gap
AM	4	Address Mark
GAP2	3	Zero Byte Gap
SYNC1	1	ID Sync Byte
GPA2	2	ID Zero Byte Gap
COM	1	ID Compare Byte
CYLH	1	Cylinder High (MSB)
CYLL	1	Cylinder Low (LSB)
FLAG	1	Flag Byte
ZER	4	Zero Byte
ECC1	4	ID ECC Bytes
GAP4	16	Zero Byte Gap
SYNC2	1	Data Field Zero Byte Gap
GAP5	2	Data Field Sync Byte
DATA	256/512	Data Field
ECC2	4	Data Field ECC Bytes
GAP6	14/43	Inter-Record Zero Gap

TABLE 4-10 FDD SECTOR/TRAK FORMAT, MFM

	DATA	# OF BYTES	FIELD DESCRIPTION
	4E	80	Post Index Gap, beginning at Index hole
	00	12	Sync Field
	C2	3	
	FC	1	Index Address
	4E	50	Gap
	00	12	Sync Field
	A1	3	
	FE	1	I.D. Address Mark
	XX	1	Track Number (range 0 to FE)
	0X	1	Head Number (range 0 to E)
Repeated Once for Each Sector	XX	1	Sector Length (X = 1,2: Sector length = 256, 512)
	XX	2	CRC
	4E	22	Gap
	00	12	Sync Field
	A1	3	
	FB	1	Data Address Mark
	40	?	Data field (# bytes = 256, 512)
	XX	2	CRC
	4E	54	Gap
	4E	?	Pre index gap. Written from end of last sector to index hole.

The data fields are formatted with 40 (Hex) as the data.

TABLE 4-11 FDD SECTOR/TRACK FORMAT, FM

	DATA	# OF BYTES	FIELD DESCRIPTION
	FF	40	Post Index Gap, beginning at Index hole
	00	6	Sync Field
	FC	1	Index Address
	FF	26	Gap
	00	6	Sync Field
	FE	1	I.D. Address Mark
	XX	1	Track Number (range 0 to FE)
	0X	1	Head Number (range 0 to E)
Repeated Once for Each Sector	XX	1	sector Number (range 0 to FE)
	0X	1	Sector Length (X = 0,1,2: Sector length = 128, 256, 512)
	XX	2	CRC
	FF	11	Gap
	00	6	Sync Field
	FB	1	Data Address Mark
	E5	?	Data field (# bytes = 128, 256, 512)
	XX	2	CRC
	FF	27	Gap
	FF	?	Pre index gap. Written from end of last sector to index hole.

The data fields are formatted with E5 (Hex) as the data.

EXECUTION OF DIAGNOSTICS

Since all of the diagnostics are not executed by the Controller on power up, it is suggested that they be envoked by the host in the following order:

1) Controller internal diagnostics (Command code E4). This diagnostic tests all the logical and decision making capability of the controller as well as the program memory checksum and the error detection and correction circuits (ECC). Execution of this diagnostic ensures that the Controller can communicate with the host.

2) The Ram Diagnostic (Command code E0) should be executed next. This command verifies that the sector buffer is operational by writing, reading and verifying various data patterns to and from all locations.

3) Before the Drive Diagnostic is executed, the host program should continuously issue a Test Drive Ready command to the controller (Command code 00) with the appropriate time-out until the drive becomes ready.

5) Drive Diagnostic (Command code E3). This diagnostic issues a Recalibrate to the disk drive and then steps through all tracks verifying the ECC on the identifier fields of the first sector of each track, then writes and reads one sector in each head of the maintenance cylinder. If this diagnostic passes, it implies that the disk has been formatted and that the first ID field of each track is good and the drive can write and read.

4.8 ERROR CORRECTION PHILOSOPHY

Since the typical error correction time of the S1420 controller is approximately 50 milliseconds and therefore greater than the time for one revolution of the disk, the sector in error is optionally re-read (if bit 6 is set in byte 5 of the read command DCB) on the next revolution during a Read command. In most cases, the error will be soft and will not reappear on the re-read. This initial re-read of the failing sector is over and above the retry count passed in the DCB which applies only to uncorrectable ECC errors (bit 7, byte 5).

The retry count on uncorrectable errors is preset to 4 by the controller each time a sector has been read successfully. On a multiple sector transfer if an uncorrectable error was detected but subsequently found to be correctable on a retry, the retry count is reset to 4 before the next sector is read from the disk.

ALTERNATE TRACK ASSIGNMENT AND HANDLING

The assignment of alternate tracks or lockout of defective tracks must be done by the host computer. One procedure for initializing a disk and assigning alternate tracks is as follows:

1) The entire disk drive is formatted by issuing a Format Disk command (Command Code 04) starting at logical address zero.

   If an error occurs during formatting, a Request Sense command is issued to retrieve the error code and disk address. The defective track address is determined from the last three request sense data bytes. Another Format Disk command is issued starting at the track following the defective track. If other errors occur, the process is repeated until the disk is formatted. The host must maintain the list of defective tracks. All defective tracks should be formatted using the format bad track command to make verifying easier.

2) Now, the entire disk is read verified to check for uncorrectable data errors. Any track that contains an uncorrectable error is added to the defective track list by the host. If all defective tracks have been formatted bad, the read verify command will terminate with an "Access to Defective Track" Error (code 19) when a read is attempted from that track. Software then knows to advance the disk address to the next track and continue verifying. It is a good idea to reduce the ECC correction length during verify. This ensures that a correctable data error does not become uncorrectable later because the number of defective bits increased.

3) Steps 1 and 2 should be repeated using different data patterns for each pass. This is done easily by issuing a Write Buffer command with the data pattern followed by a Format command with bit 5 of the control byte (byte 5) of the DCB set. Three to five passes should be sufficient.

Next, pick an alternate track area on the disk. The alternate track area usually resides at the highest numbered disk tracks. The area should be of sufficient size to allow one alternate track per 50 to 100 tracks on the drive. Each defective track in the list created in steps 2 and 3 is reassigned to the alternate track area by using the Assign Alternate Track command. If any tracks in the alternate area are defective, skip over them and use the next available track.

0 OVERLAPPING SEEKS WITH BUFFERED STEP DRIVES

For drives employing buffered seeks, seek command can be overlapped. After the controller issues a seek to the drive, it returns with a completion status, not waiting for the drive to complete the seek. If the return status shows no error, then the seek was issued correctly. If there is an error, then the seek was not issued. After transferring the status, another command can be issued to either drive. If a new command is received for a drive with an outstanding seek, then the controller will wait, with Busy active, for the seek to complete before executing the new command (Except Test Drive Ready Command).

The Test Drive Ready command can be used with overlapped seeks to determine when a drive has completed seeking before issuing the next command. If the drive is still seeking, the status byte at the end of the command will indicate an error, and the sense status will indicate "drive still seeking" (type 0 error, code 8). A sequence of Test Drive Ready commands can thus be used to determine when the drive is ready for the next command.

1 SECTOR INTERLEAVING

Variable sector interleaving is supported by the S1420. When any format command is issued, any interleave value up to the number of sectors-per-track minus one may be passed in the Device Control Block (DCB byte 4). The interleave factor may be adjusted for maximum system performance. Interleaving allows logical contiguous sectors of data on a given track to be mapped onto non-adjacent physical sectors. An interleave factor of five, for instance means that every fifth physical sector is transferred as the next contiguous logical sector of data. If the operation is read and the interleave factor is five then a sector of data is read into the sector buffer first and during the time that the heads are passing over the next three physical sectors of the disk, the data is being transferred to the host. If the host cannot transfer the full sector of data during the three sector times available, then the S1420 has to wait a full revolution before the next logical sector can be read from the disk. If this happens, the interleave factor is too low and should be increased until an increase in system speed is noticed.

In order to take full advantage of the interleaving feature of the S1420, the operating system should perform multiple sector data transfers. If single sector transfers are employed, the difference in speed with various interleave factors may not be dramatic.

The interleave value can be set to improve system throughput based on overhead time of the host software, overhead time in the disk driver, and overhead time for the S1420 to process a command. If the host system is capable of multisector transfers, system throughput can be optimized by setting the interleave value such that the next logical sector comes under the heads just as the S1420 completes the data transfer of the previous sector. If the host is capable of passing a sector of data at DMA speed (one millisecond for a 256 byte sector), then the interleave value should be set to four to optimize multisector transfers. This is the minimum value for continuous sector transfers. If a sector data transfer takes between one and two milliseconds, set the interleave value to five. The best method is to experimentally determine the best interleave value for your system using a representative benchmark.

The following table shows an example of 32 sectors-per-track with an interleave factor of 5.

PHYSICAL	LOGICAL	LOGICAL	PHYSICAL
00	00	00	00
01	13	01	05
02	26	02	10
03	07	03	15
04	20	04	20
05	01	05	25
06	14	06	30
07	27	07	03
08	08	08	08
09	21	09	13
10	02	10	18
11	15	11	23
12	28	12	28
13	09	13	01
14	22	14	06
153	03	15	11
16	16	16	16
17	29	17	21
18	10	18	26
19	23	19	31
20	04	20	04
21	17	21	09
22	30	22	14
23	11	23	19
24	24	24	24
25	05	25	29
26	18	26	02
27	31	27	07
28	12	28	12
29	25	29	17
30	06	30	22
31	19	31	27

TABLE 4-12 TRACK FORMAT EXAMPLE OF 32 SECTORS-PER-TRACK WITH AN INTERLEAVE FACTOR OF 5